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(54) **Turbofan engine with variable bypass nozzle exit area and method of operation**

Turbofan mit variabler Bypassdüsen-Austrittsfläche und Betriebsverfahren

Turboréacteur à double flux doté d'une zone de sortie variable et procédé de fonctionnement

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(73) Proprietor: **United Technologies Corporation**
Farmington, CT 06032 (US)

(72) Inventor: **Winter, Michael**
New Haven, CT Connecticut 06515 (US)

(74) Representative: **Hull, James Edward et al**
Dehns
St. Bride's House
10 Salisbury Square
London
EC4Y 8JD (GB)

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Description

BACKGROUND OF THE INVENTION

[0001] This invention relates to a turbofan engine, and more particularly, the invention relates to effectively changing a nozzle exit area of a bypass flow path.

[0002] A typical turbofan engine includes a spool supporting a compressor and a turbine. The spool, compressor and turbine are housed within a core nacelle. A turbofan, or "fan," is coupled to the spool and is arranged upstream from the core nacelle. A fan nacelle surrounds the turbofan and core nacelle. The fan and core nacelles provide a bypass flow path having a nozzle exit area through which bypass flow from the fan exits the engine.

[0003] Turbofan engines typical have a fixed nozzle exit area. The flow through the nozzle affects, for example, the operational line of the fan and compressor and the overall performance and efficiency of the engine. Since the nozzle exit area is fixed, the operational lines and other engine operating characteristics must be managed using a more limited number of engine parameters. The engine parameters are varied during engine operation to obtain desired engine operating characteristics, such as fuel efficiency. What is needed is a method and apparatus of managing engine operating characteristics by using the nozzle exit area as an additional variable parameter. What is also needs is an ability to use the nozzle exit area as a variable parameter with minimal cost and weight penalties.

[0004] Prior art gas turbine engines are disclosed in FR-923,996, US-3,688,504 and US-2,703,477.

SUMMARY OF THE INVENTION

[0005] According to the present invention, there is provided a turbofan engine as claimed in claim 1 and a method as claimed in claim 7.

[0006] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

Figure 1 is a cross-sectional view of an example turbofan engine.

Figure 2a is a schematic partial side cross-sectional view of a turbofan engine with a flow control device expelling fluid in a first manner.

Figure 2b is a schematic partial end view of the turbofan engine shown in Figure 2a.

Figure 3a is a schematic partial side cross-sectional view of a turbofan engine with the example flow control device expelling fluid in a second manner.

Figure 3b is a schematic partial end view of the turbofan engine shown in Figure 3a.

Figure 4 is a schematic partial side cross-sectional view of the turbofan engine with another example flow control device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0008] A geared turbofan engine 10 is shown in Figure 1. A pylon 38 secures the engine 10 to an aircraft. The engine 10 includes a core nacelle 12 that houses a low spool 14 and high spool 24 rotatable about an axis A. The low spool 14 supports a low pressure compressor 16 and low pressure turbine 18. In the example, the low spool 14 drives a turbofan 20 through a gear train 22. The high spool 24 supports a high pressure compressor 26 and high pressure turbine 28. A combustor 30 is arranged between the high pressure compressor 26 and high pressure turbine 28. Compressed air from compressors 16, 26 mixes with fuel from the combustor 30 and is expanded in turbines 18, 28.

[0009] In the examples shown, the engine 10:1 is a high bypass turbofan arrangement. In one example, the bypass ratio is greater than 10, and the turbofan diameter is substantially larger than the diameter of the low pressure compressor 16. The low pressure turbine 18 has a pressure ratio that is greater than 5:1, in one example. The gear train 22 is an epicycle gear train, for example, a star gear train, providing a gear reduction ratio of greater than 2.5:1. It should be understood, however, that the above parameters are only exemplary of a contemplated geared turbofan engine. That is, the invention is applicable to other engines including direct drive turbofans.

[0010] Airflow enters a fan nacelle 34, which surrounds the core nacelle 12 and turbofan 20. The turbofan 20 directs air into the core nacelle 12, which is used to drive the turbines 18, 28, as is known in the art. Turbine exhaust E exits the core nacelle 12 once it has been expanded in the turbines 18, 28, in a passage provided between the core nacelle and a tail cone 32.

[0011] The core nacelle 12 is supported within the fan nacelle 34 by structure 36, which are commonly referred to as upper and lower bifurcations. A generally annular bypass flow path 39 is arranged between the core and fan nacelles 12, .34. The example illustrated in Figure 1 depicts a high bypass flow arrangement in which approximately eighty percent of the airflow entering the fan nacelle 34 bypasses the core nacelle 12. The bypass flow B within the bypass flow path 39 exits the fan nacelle 34 through a nozzle exit area 40.

[0012] For the engine 10 shown in Figure 1, a significant amount of thrust may be provided by the bypass flow B due to the high bypass ratio. Thrust is a function of density, velocity and area. One or more of these parameters can be manipulated to vary the amount and direction of thrust provided by the bypass flow B. In one example, the engine 10 includes a structure associated with the nozzle exit area 40 to change the physical area

and geometry to manipulate the thrust provided by the bypass flow B. However, it should be understood that the nozzle exit area may be effectively altered by other than structural changes, for example, by altering the boundary layer, which changes the flow velocity. Furthermore, it should be understood that any device used to effectively change the nozzle exit area is not limited to physical locations near the exit of the fan nacelle 34, but rather, includes altering the bypass flow B at any suitable location.

[0013] The engine 10 has a flow control device 41 that is used to effectively change the nozzle exit area. In one example, the flow control device 41 provides the fan nozzle exit area 40 for discharging axially the bypass flow B pressurized by the upstream turbofan 20 of the engine 10. A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The turbofan 20 of the engine 10 is designed for a particular flight condition, typically cruise at 0.8M and 35,000 feet (10,668 m). The turbofan 20 is designed at a particular fixed stagger angle for an efficient cruise condition. The flow control device 41 is operated to vary the nozzle exit area 40 to adjust fan bypass air flow such that the angle of attack or incidence on the fan blade is maintained close to design incidence at other flight conditions, such as landing and takeoff. This enables desired engine operation over a range of flight condition with respect to performance and other operational parameters such as noise levels. In one example, the flow control device 41 defines a nominal converged position for the nozzle exit area 40 at cruise and climb conditions, and radially opens relative thereto to define a diverged position for other flight conditions. The flow control device 41 provides an approximately 20% change in the exit nozzle area 40.

[0014] Referring to Figures 2a-4, a flow control device is shown that uses a fluid, such as air, to vary a boundary layer Q within the bypass flow path 39 to effectively change the nozzle exit area 40. The boundary layer Q is created by the bypass flow B along the walls of the bypass flow path 39.

[0015] In the examples shown in Figures 2a-3b, the flow control device 41 uses bleed air L from one of the compressor stages 54. The bleed air L is introduced to the bypass flow path 39 in a desired manner to affect the boundary layer Q. It is typically desirable to extract bleed air L from the lowest usable compressor stage to minimize the efficiency impact on the engine. In one example, the compressor stage 54 corresponds to an upstream compressor stage on the high compressor 26. In one example, extraction of bleed air L is avoided during particular engine operating conditions, such as cruise.

[0016] In one example, a controller 50 commands a valve 55 arranged in a passage 52. The passage 52 fluidly connects the compressor stage 54 to apertures 56 arranged on a surface 57 adjacent to the bypass flow path 39. Three apertures 56 are shown for exemplary purposes. The apertures 56 can be arranged in an array and plumbed in any suitable manner. The valve 55 selectively regulates the bleed air L provided through the apertures 56 in response to commands from the controller 50 to obtain a desired boundary layer thickness. The controller 50 determines when changes in the effective nozzle exit area 40 are desired for a particular engine operating characteristic.

[0017] Decreasing the boundary layer at the surface 57 effectively "opens" the nozzle exit area 40. A decrease in boundary layer Q increases the mean velocity of bypass flow B across the nozzle exit area 40. Conversely, increasing the boundary layer Q at the surface 57 effectively "closes" the nozzle exit area 40. An increase in boundary layer decreases the mean velocity of bypass flow B across the nozzle exit area 40.

[0018] In the engine shown in Figures 2a-2b not within the scope of the present invention, the apertures 56 introduce the bleed air L in a direction generally perpendicular to the bypass flow B, which effectively increases the boundary layer Q and provides and effective closing of the nozzle exit area 40. The bypass flow B in Figures 2b and 3b are indicated in a generally axial direction.

[0019] In the example shown in Figures 3a-3b, the apertures 56' are arranged generally tangentially to the bypass flow B so that introducing the bleed air L effectively opens the nozzle exit area 40 by decreasing the boundary layer.

[0020] In either approach shown in Figures 2a-2b and Figures 3a-3b, the bleed air L provides a range of effective nozzle exit areas 40 between no-bleed flow and bleed flow conditions. Said another way, in one example, one of the aperture orientations shown in the Figures is chosen. With the chosen aperture configuration, the flow of bleed air L is adjusted to obtain the desired boundary layer Q. In this manner, the flow control device 41 provides another engine parameter by which the engine operating characteristics can be managed.

[0021] Another example flow control device 41' is shown in Figure 4. In one example, the flow control device 41' uses a chamber 58 to provide pulsed flow to the surface 57 through passages 60 to the apertures 56. In one example, the chamber 58 is tuned to provide air to the bypass flow path 39 at a desired frequency. An exciter 64 is actuated by a driver 66 in response to a command from the controller 50. The exciter 64 create pulses that are delivered to through the apertures 56 to change the boundary layer Q. The driver 66 modulates the exciter 64 at a desired frequency to obtain a desired boundary layer Q. The aperture 56 and chamber 58 geometry are selected to achieve the desired boundary layer Q. The apertures 56 can be arranged in any suitable manner, for example in the manner described above relative to Figures 2a-3b.

[0022] Although an example embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

Claims

1. A turbofan engine (10) comprising:

   core and fan nacelles (12, 34) providing a bypass flow path (39) having a nozzle exit area (40), the bypass flow path (39) carrying a bypass flow (B) to be expelled from the nozzle exit area (40);
   a turbofan (20) arranged within the fan nacelle (34) and upstream from the core nacelle (12) for generating the bypass flow (B);
   a spool (14) having a turbine (18) mounted thereon and housed within the core nacelle (12);
   a gear train (22) interconnecting the turbofan (20) and the spool (14), the turbofan (20) coupled to the spool (14) through the gear train (22); and
   a flow control device (41) including a surface (57) in the bypass flow path (39) including an aperture (59), the flow control device (41) adapted to introduce a fluid (L) into the bypass flow path (39) through the aperture (56) for decreasing a boundary layer (Q) of the bypass flow (B) that effectively changes the nozzle exit area, wherein the flow control device (41) includes a controller (50) programmed to command a valve (55) regulating a flow of the fluid through the aperture (56).

2. The turbofan engine (10) according to claim 1, comprising a flow source for providing the fluid (L).

3. The turbofan engine (10) according to claim 2, comprising a compressor (26) arranged within the core nacelle (12), the compressor (26) providing bleed air as the fluid (L).

4. The turbofan engine (10) according to claim 3, comprising a low spool (14) and a high spool (24) rotatable relative to one another and housed within the core nacelle (34), the compressor (26) mounted on the high spool (24), and the turbofan (20) coupled to the low spool (14) through the gear train (22).

5. The turbofan engine (10) according to claim 1, wherein the flow control device (41) includes a chamber (58) in fluid communication with the bypass flow (B), the chamber (58) providing a pulse of the fluid (L).

6. The turbofan engine (10) according to claim 5, wherein the flow control device (41) includes a controller (50) programmed to command an exciter (64) that is in communication with the chamber (58), the exciter (64) being driven in response to the command at a desired frequency.

7. A method of controlling a geared turbofan engine (10), said method comprising the steps of:

   introducing a fluid (L) into a turbofan bypass flow path (39) to alter a bypass flow (B) through the bypass flow path (39); and
   effectively changing a nozzle exit area (40) of the bypass flow path (39) with the altered bypass flow (B) by decreasing a boundary layer (Q) along a surface (57) within the bypass flow path (39) using the fluid (L), wherein the flow of fluid (L) into the bypass flow path (39) is regulated using a controller (50) that commands a valve (55).

Patentansprüche

1. Turbofan (10), der Folgendes umfasst:

   Kern- und Fan-Gondel (12, 34), die einen Bypassströmungspfad (39) bereitstellen, der eine Düsenaustrittsfläche (40) aufweist, wobei der Bypassströmungspfad (39) einen Bypassstrom (B) trägt, der aus der Düsenaustrittsfläche (40) ausgestoßen werden soll;
   einen Turbofan (20), der zum Erzeugen des Bypassstroms (B) innerhalb der Fan-Gondel (34) angeordnet ist und der Kerngondel (12) vorgelagert ist;
   eine Spule (14), die eine Turbine (18) aufweist, die darauf angebracht ist und innerhalb der Kerngondel angebracht ist (12);
   ein Getriebe (22), das den Turbofan (20) und die Spule (14) verbindet, wobei der Turbofan (20) durch das Getriebe (22) an die Spule (14) gekoppelt ist; und
   eine Strömungssteuerungsvorrichtung (41), die eine Oberfläche (57) in dem Bypassströmungspfad (39) beinhaltet, der eine Öffnung (59) beinhaltet, wobei die Strömungssteuerungsvorrichtung (41) dazu ausgebildet ist, ein Fluid (L) zum Verringern einer Grenzschicht (Q) des Bypassstroms (B), der die Düsenaustrittsfläche effektiv ändert, durch die Öffnung (56) in den Bypassströmungspfad (39) einzuführen, wobei die Strömungssteuervorrichtung (41) eine Steuerung (50) beinhaltet, die dazu programmiert ist, ein Ventil (55), das einen Strom des Fluides durch die Öffnung (56) reguliert, zu befehlen.

2. Turbofan (10) nach Anspruch 1, der eine Strömungsquelle zum Bereitstellen des Fluides (L) umfasst.

3. Turbofan (10) nach Anspruch 2, der einen Kompressor (26) umfasst, der innerhalb der Kerngondel (12) angeordnet ist, wobei der Kompressor (26) Zapfluft als das Fluid (L) bereitstellt.

4. Turbofan (10) nach Anspruch 3, der eine niedrige Spule (14) und eine hohe Spule (24) umfasst, die relativ zueinander drehbar sind und innerhalb der Kerngondel (34) umschlossen sind, wobei der Kompressor (26) auf der hohen Spule (24) angebracht ist und der Turbofan (20) durch das Getriebe (22) an die niedrige Spule (14) gekoppelt ist.

5. Turbofan (10) nach Anspruch 1, wobei die Strömungssteuerungsvorrichtung (41) eine Kammer (58) beinhaltet, die in Fluidverbindung mit dem Bypassstrom (B) steht, wobei die Kammer (58) einen Puls des Fluides (L) bereitstellt.

6. Turbofan (10) nach Anspruch 5, wobei die Strömungssteuervorrichtung (41) eine Steuerung (50) beinhaltet, die dazu programmiert ist, einen Anreger (64) zu befehlen, der in Kommunikation mit der Kammer (58) steht, wobei der Anreger (64) als Reaktion auf den Befehl mit einer gewünschten Frequenz betrieben wird.

7. Verfahren zum Steuern eines Turbofans mit Getriebe (10), wobei das Verfahren die folgenden Schritte umfasst:

Einführen eines Fluides (L) in einen Turbofan-Bypassströmungspfad (39), um einen Bypassstrom (B) durch den Bypassströmungspfad (39) zu ändern; und
effektives Ändern einer Düsenaustrittsfläche (40) des Bypassströmungspfads (39) mit dem geänderten Bypassstrom (B) durch Verringern einer Grenzschicht (Q) entlang einer Oberfläche (57) innerhalb des Bypassströmungspfads (39) unter Verwendung des Fluides (L), wobei der Strom des Fluides (L) in den Bypassströmungspfad (39) unter Verwendung einer Steuerung (50), die ein Ventil (55) befiehlt, reguliert wird.

Revendications

1. Moteur à double flux (10), le moteur comprenant :

des nacelles centrales et de soufflante (12, 34) présentant une voie de passage de dilution (39) comportant une zone de sortie de tuyère (40), la voie de passage de dilution (39) permettant l'acheminement d'un flux de dilution (B) devant être expulsé de la zone de sortie de tuyère (40) ;
un turboréacteur (20) disposé à l'intérieur de la nacelle de soufflante (34) et en amont de la nacelle centrale (12) pour générer le flux de dilution (B) ;
un corps (14) sur lequel est montée une turbine (18) et logé dans la nacelle centrale (12) ;
un train d'engrenages (22) reliant le turboréacteur (20) et le corps (14), le turboréacteur (20) étant couplé au corps (14) à travers le train d'engrenages (22) ; et
un dispositif de commande de flux (41) comprenant une surface (57) dans la voie de passage de dilution (39) comprenant une ouverture (59), le dispositif de commande de flux (41) étant conçu pour introduire un fluide (L) dans la voie de passage de dilution (39) à travers l'ouverture (56) pour réduire une couche limite (Q) du flux de dilution (B) qui modifie de manière effective la zone de sortie de tuyère, le dispositif de commande de flux (41) comprenant un élément de commande (50) programmé pour commander une soupape (55) régulant un débit du fluide à travers l'ouverture (56).

2. Moteur à double flux (10) selon la revendication 1, comprenant une source de flux pour fournir le fluide (L).

3. Moteur à double flux (10) selon la revendication 2, comprenant un compresseur (26) agencé à l'intérieur de la nacelle centrale (12), le compresseur (26) fournissant de l'air de prélèvement en tant que fluide (L).

4. Moteur à double flux (10) selon la revendication 3, comprenant un corps inférieur (14) et un corps supérieur (24) pouvant tourner l'un par rapport à l'autre et logés dans la nacelle centrale (34), le compresseur (26) étant monté sur le corps supérieur (24), et le turboréacteur (20) couplé au corps inférieur (14) à travers le train d'engrenages (22).

5. Moteur à double flux (10) selon la revendication 1, dans lequel le dispositif de commande de flux (41) comprend une chambre (58) en communication fluidique avec le flux de dilution (B), la chambre (58) fournissant une impulsion du fluide (L).

6. Moteur à double flux (10) selon la revendication 5, dans lequel le dispositif de commande de flux (41) comprend un élément de commande (50) programmé pour commander un excitateur (64) en communication avec la chambre (58), l'excitateur (64) étant entraîné à une fréquence souhaitée en réponse à la commande.

7. Procédé de commande d'un moteur à double flux à engrenages (10), ledit procédé comprenant les étapes consistant à :

introduire un fluide (L) dans une voie de passage de dilution d'un turboréacteur (39) pour modifier un flux de dilution (B) à travers la voie de passage de dilution (39) ;
et changer efficacement une zone de sortie de

tuyère (40) de la voie de passage de dilution (39) avec le flux de dilution modifié (B) en réduisant une couche limite (Q) le long d'une surface (57) dans la voie de passage de dilution (39) en utilisant le fluide (L), dans lequel le débit de fluide (L) dans la voie de passage de dilution (39) est régulé en utilisant un élément de commande (50) qui commande une soupape (55).

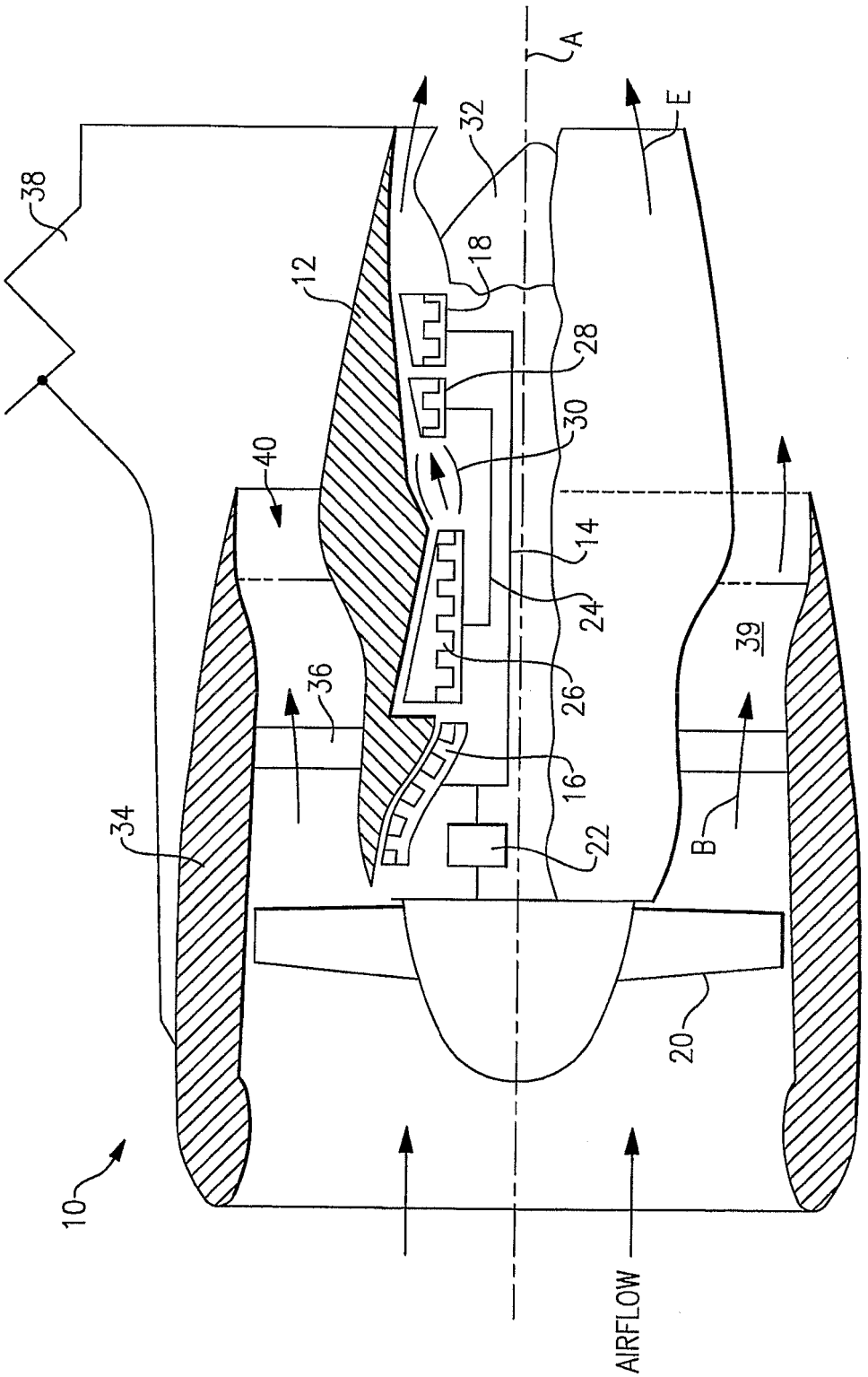


FIG.1

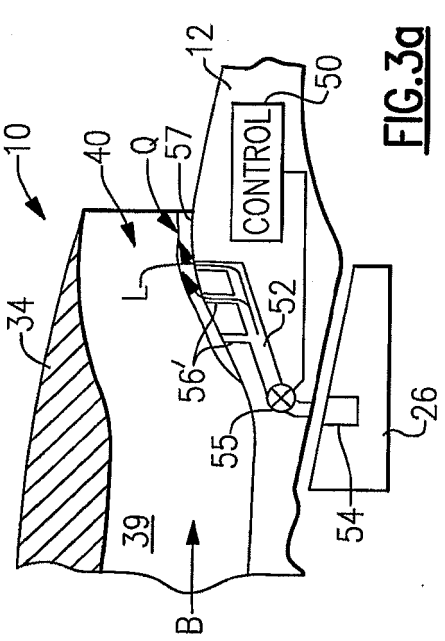


FIG.3a

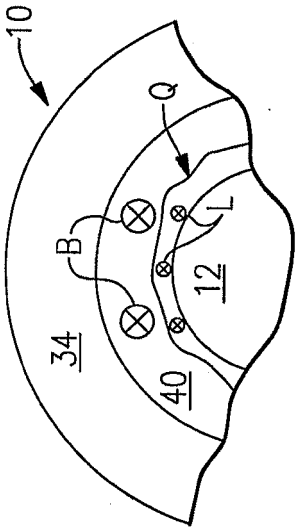


FIG.3b

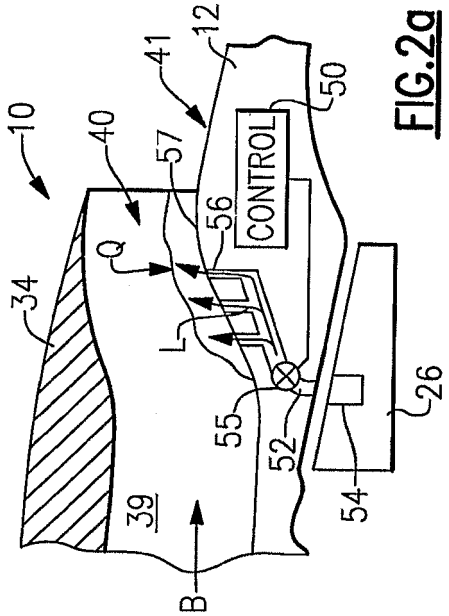


FIG.2a

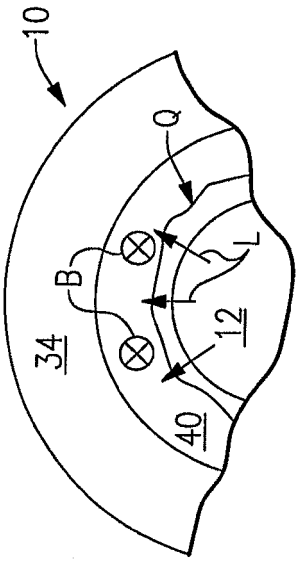


FIG.2b

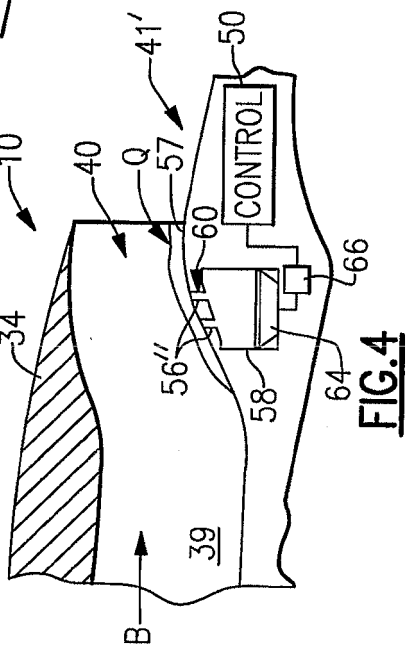


FIG.4

REFERENCES CITED IN THE DESCRIPTION

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